Quality Assurance Project Plan

for

Hydrodynamic and Water Quality Modeling for Lake Thunderbird (Oklahoma)

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Lake Water Quality Modeling – Lake Thunderbird

March 12, 2010

SECTION A: PROJECT MANAGEMENT

A1 APPROVALS

Oklahoma Department of Environmental Quality (DEQ)

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Shellie Chard-McClary, Director Date
Water Quality Division

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Mark Derichsweiler, Planning Section Manager Date
Water Quality Division

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Andrew Fang, Project Manager Date
Planning Section, Water Quality Division

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Karen Khalafian, Date
Quality Assurance Officer, DEQ

____

Karen Miles, Date
Quality Assurance Coordinator, Water Quality Division

Oklahoma Office of the Secretary of the Environment

____

Gayle Bartholomew Date
Environmental Grants Administrator

APPROVALS (Continued)

Dynamic Solutions, LLC

____

Christopher Wallen, Project Manager Date
Dynamic Solutions, LLC

____

Julie Wallen, Quality Assurance Officer Date
Dynamic Solutions, LLC

U.S. Environmental Protection Agency, Region 6

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EPA Approving Official Date
EPA Region 6, Office of Water Quality

____

Kara Alexander, Date
Project Officer, EPA Region 6

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LIST OF ACRONYMS AND ABBREVIATIONS

AVI	Audio Video Interleaved (Windows multimedia format)
BMP	Best Management Practice (for nonpoint source controls)
BUMP	Beneficial Uses Monitoring Program
CAR	Corrective Action Report
CASTNET	Clean Air Status and Trends Network
COD	Chemical Oxygen Demand
COMCD	Central Oklahoma Master Conservancy District
CST	Central Standard Time Zone
DO	Dissolved Oxygen
DSLLC	Dynamic Solutions
DEM	Digital Elevation Model
DQO	Data Quality Objective
DEQ	Oklahoma Department of Environmental Quality
EFDC	Environmental Fluid Dynamics Code
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrologic Simulation Fortran Program
HUC	Hydrologic Unit Code for Catalog Units
LA	Load Allocation
NAD83	North American Datum of 1983
NADP	National Atmospheric Deposition Program
NAVD88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic Atmospheric Administration
NED	National Elevation Data Set from USGS
NHD	National Hydrography Data Set from USGS
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NWIS	National Water Information System
OCC	Oklahoma Conservation Commission
OSE	Oklahoma Office of the Secretary of the Environment
OWRB	Oklahoma Water Resources Board
PCS	Permit Compliance System
PM	Project Manager
PS	Point Source
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAO	Quality Assurance Officer
QAM	Quality Assurance Manual (or Manager)

QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
RMS	Root Mean Square
RMS-Error	Root Mean Square Error
SOD	Sediment Oxygen Demand
SOP	Standard Operating Procedure
STORET	EPA Storage and Retrieval System
SWS	Sensitive Water Supply
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
USBOR	United States Bureau of Reclamation
USCOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator (map projection)
WLA	Waste Load Allocation

A3 DISTRIBUTION LIST

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A4 PROJECT TASK ORGANIZATION

The assessor for this project will be the Oklahoma DEQ Project Manager and the management of the DEQ Water Quality Division. Others are available for technical consulting as requested, including the participants at Dynamic Solutions, LLC, the Water Quality Division's QA Coordinator and the Department's QA Officer. Water Quality Division Management has the ultimate authority to continue or modify work in a significant fashion, based on the recommendations of the DEQ Project Manager or other involved parties. The DEQ Project Manager is responsible for modifying conditions to achieve results which he believes are realistic and supportable by actual conditions, and which he thinks would reflect probable results should future sampling be undertaken in attempts to verify modeling results.

The following individuals are involved in implementing this project:

Kara Alexander – US EPA Region 6, Project Officer
The Project Officer is responsible for managing this project for EPA, Region 6. The Project Officer reviews project progress and reviews and approves QAPP and QAPP amendments.

Mark Derichsweiler – DEQ Water Quality Division Section Manager
The DEQ Section Manager is responsible for direct supervision of the DEQ Project Manager and reporting progress on the project to other managers in the DEQ Water Quality Division (WQD).

Andrew Fang – DEQ Project Manager
The DEQ Project Manager is responsible for planning and oversight of the project for the DEQ. He is responsible for ensuring that the project and its resulting deliverables meet the requirements of the USEPA-approved work plan, and will assist in managing and improving water quality in the State of Oklahoma. He is responsible for developing and managing contracts with Dynamic Solutions to achieve work plan objectives. He reviews project deliverables to ensure that the tasks in the work plan are completed as specified, and data is of known and sufficient quality, as specified in this QAPP.

Karen Khalafian – DEQ Quality Assurance (QA) Officer
Reviews and approves QAPPs (including any amendments or revisions) to ensure that a project will deliver data of known and sufficient quality to achieve project objectives. Conveys QA problems to appropriate DEQ management. Monitors implementation of corrective actions.

Karen Miles – DEQ WQD QA Coordinator
Reviews and approves QAPPs (including any amendments or revisions) to ensure that a project will deliver data of known and sufficient quality to achieve project objectives. Conveys QA problems to appropriate DEQ Water Quality Division (WQD) management. Monitors implementation of corrective actions.

Christopher Wallen – Dynamic Solutions Project Manager
The Dynamic Solutions Project Manager is responsible for executing the tasks and other requirements of the contract on time and with the quality assurance/quality control requirements

in the system as defined by the contract and in the project QAPP; submitting accurate and timely deliverables to the DEQ Water Quality Division Project Manager and attending conference calls, training, meetings, and related modeling project activities with DEQ. Responsible for producing data and modeling products of known and acceptable quality in accordance with this QAPP. Responsible for ensuring adequate training and supervision of all activities involved in generating data and model results, including the facilitation of audits and the implementation, documentation, verification and reporting of corrective actions to the DEQ Water Quality Division Project Manager.

Julie Wallen – Dynamic Solutions QA Officer
Responsible for developing and implementing Dynamic Solutions' QA program. Responsible for writing and maintaining QAPPs and monitoring their implementation. Responsible for maintaining records of QAPPs , including appendices and amendments. Ensures the data generated for the project is of known and acceptable quality and adheres to the specifications of the QAPP. Responsible for identifying, receiving, and maintaining project quality assurance records. Responsible for compiling and submitting QA reports to DEQ Water Quality Division. Responsible for coordinating with the DEQ QAS to resolve any QA-related issues. Notifies the DEQ Project Manager of particular circumstances which may adversely affect the quality of the products. Conducts the research and review of technical QA material and data related to the model system design and analytical techniques. Implements or ensures implementation of corrective actions needed to resolve nonconformances noted during assessments.

Andrew Stoddard – Dynamic Solutions Project Leader and Data Manager
Responsible for the acquisition, verification, and transfer of applicable data and/or model inputs and outputs to the DEQ Project Manager. Oversees data management and all modeling activities for the project. Performs data quality assurances prior to transfer of data and all model input/output files to DEQ. Ensures that data is submitted in the format specified in the contract or by the DEQ Project Manager. Provides the point of contact for the DEQ Project Manager to resolve issues related to the project data and assumes responsibility for the correction of any data errors.

Paul Craig- Dynamic Solutions Project Engineer
Responsible for maintenance of the current versions of software codes for the EFDC numerical model and the EFDC_Explorer pre- and post-processor. Works with Andrew Stoddard to ensure technical accuracy of model development and model calibration.

Zhijun Liu – Dynamic Solutions Project Engineer
Works with Andrew Stoddard in data processing, development and calibration of the model for this project.

Sang Yuk – Dynamic Solutions Project Engineer
Works with Andrew Stoddard in data processing, development and calibration of the model for this project.

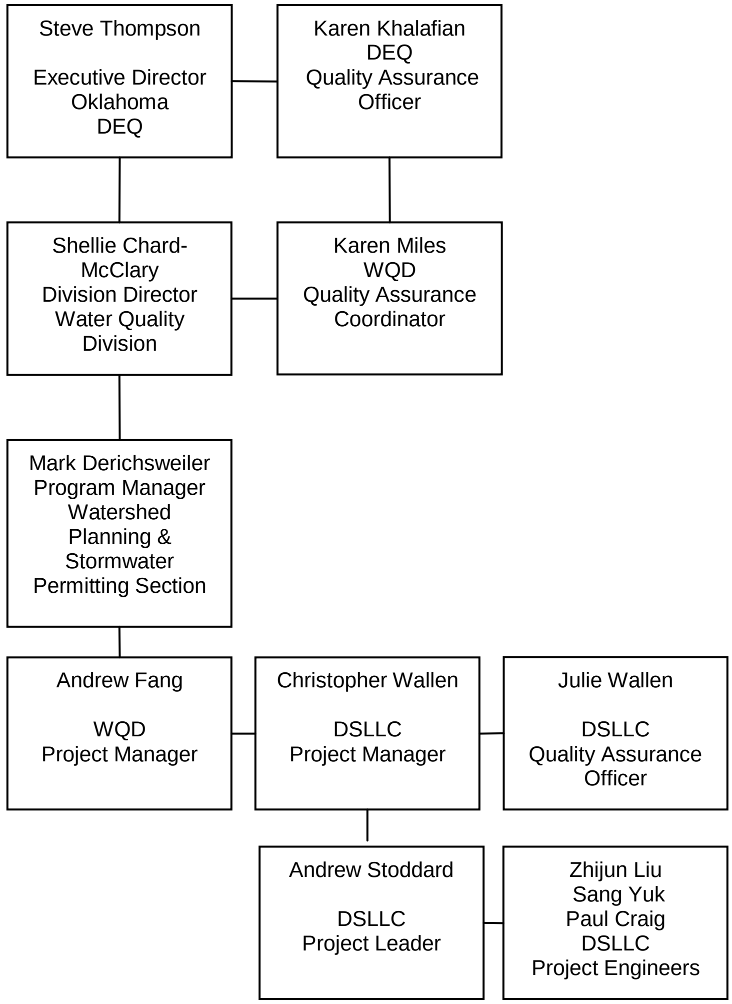

Figure A-1: Organization Chart for Lake Thunderbird Modeling Project

A5 PROBLEM DEFINITION/BACKGROUND

Lake Thunderbird (OK Waterbody Identification number OK520810000020_00), a 6,070-acre reservoir lake located at 35.222344 latitude and –97.257328 longitude in Cleveland County within the Little River drainage basin, was constructed in 1965 and is owned by the U.S. Bureau of Reclamation. Figure A-2 shows the location of the lake in the upper reaches of the Little River drainage basin. The Little River basin is identified by Hydrologic Unit Code (HUC) 11090203 for this catalog unit. The lake is listed on Oklahoma's 2008 303 (d) list for impaired beneficial uses of public/private water supply and warm water aquatic community life (DEQ, 2008). Causes of impairment have been identified in the 2008 Oklahoma Integrated Report[1] as low

[1] http://www.deq.state.ok.us/wqdnew/305b_303d/2008_integrated_report_entire_document.pdf, Appendix C, page 67.

oxygen levels, high algae biomass levels, and high turbidity. Lake Thunderbird is classified as a Nutrient Limited Watershed in Oklahoma Water Quality Standards (WQS) (785:45-5-29[2] (OWRB, undated) based on Carlson's (1977) Trophic State Index (TSI). Precise sources of nutrient loading that are causally related to nutrient enrichment are unknown although it is generally thought that nonpoint source loading from watershed runoff of nutrients, sediments and organic matter is the cause of the impairments. Lake Thunderbird, an important recreational lake for fishing and boating, is also identified as a Sensitive Water Supply (SWS) [WQS 785:45-5-25(c)(4)[3]] since the lake serves as a public water supply source for the cities of Norman, Midwest City and Del City. With the three major municipalities of Norman, Midwest City and Oklahoma City in the watershed, this area is one of the fastest growing regions in Oklahoma. With considerable urban development over the past decade and continued urban development forecasts by local governments, there is concern about the need for appropriate mitigation of the ecological impact of nonpoint sources of pollutant loading from the watershed to Lake Thunderbird.

Instead of the typical TMDL study that is usually developed to address water quality issues in impaired waters, the Oklahoma DEQ will develop a watershed-based management plan. An important component of the watershed plan will be the identification of potential load reductions needed to control nonpoint source loading of nutrients, organic matter and sediments to attain compliance with water quality targets for restoration of the lake to its designated beneficial uses. The technical basis for the determination of the required watershed load reductions will be a surface water model framework where the results generated with an HSPF (Hydrologic Simulation Fortran Program) watershed runoff model will be linked for input to an EFDC (Environmental Fluid Dynamics Code) lake hydrodynamic and water quality model. The watershed and lake model framework proposed for this work will, after the models are calibrated, be used to assess the effectiveness of alternative Best Management Practices (BMPs) and other load reduction scenarios needed to attain compliance with Oklahoma water quality standards and defined water quality targets for turbidity, chlorophyll-*a*, TSI and dissolved oxygen (DO).

The calibrated watershed, hydrodynamic and water quality model of Lake Thunderbird that will be developed under this project will provide DEQ with a scientifically defensible framework that can be used to support the development of the watershed management plan for Lake Thunderbird. DEQ has selected the HSPF model (Bicknell et al., 2001) as the watershed model of choice for Lake Thunderbird. DEQ has also identified the EFDC model (Hamrick, 1992; 1996; Park et al., 2000) as the hydrodynamic and water quality model of choice for the lake. DEQ is responsible for development of the watershed runoff model with DEQ staff. Dynamic Solutions is responsible for development of the EFDC hydrodynamic and water quality model of the lake.

[2] http://www.owrb.ok.gov/util/rules/pdf_rul/Chap45.pdf, page 24.

[3] http://www.owrb.ok.gov/util/rules/pdf_rul/Chap45.pdf, pages 21 and 67.

The purpose of this QAPP is to clearly delineate Dynamic Solutions' QA policy, management structure and procedures to implement the QA requirements necessary to verify, and calibrate the output of the modeling process associated with this project. Review of this QAPP is performed by the DEQ to help ensure that the outputs and data generated for the purposes described herein are scientifically valid and legally defensible. The process will facilitate the use of project outputs and data by the DEQ Water Quality Division and other programs deemed appropriate by the DEQ.

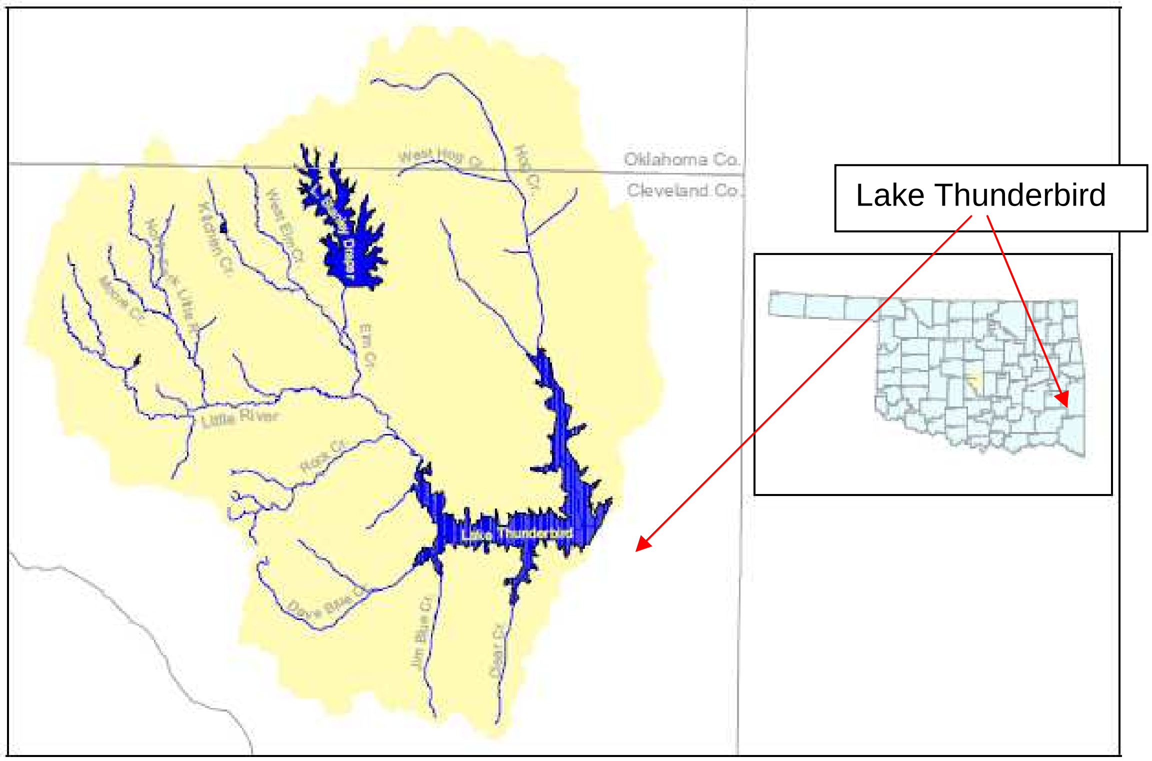

Figure A-2: Location of Lake Thunderbird within Upper Reaches of Little River HUC 11090203 in Cleveland County, Oklahoma.

A6 PROJECT/TASK DESCRIPTION AND SCHEDULE

The task description and the schedule of work for the sub-tasks related to the determination of a watershed loading plan for constituents affecting compliance with water quality targets for dissolved oxygen, nutrients, algae and turbidity in Lake Thunderbird are presented for the following three task areas:

<u>Task 1: Quality Assurance Project Plan (QAPP)</u>
1A: Draft QAPP — Submit: Week of February 9, 2010
1B: Final QAPP — Submit: Week of April 12, 2010

<u>Task 2: Water Quality Modeling</u>
2A: Data Compilation and Data Inventory

2B: Model Setup
2C: Linkage of HSPF Watershed Model Results for Input to EFDC Lake Model
Sub-Tasks 2A, 2B and 2C Complete by Week of April 26, 2010

2D: Hydrodynamic and Water Quality Model Calibration
2E: Water Quality Targets
2F: Evaluation of Load Reductions for Nutrients and Sediments 2G: In-Lake Mitigation Scenarios
Sub-Tasks 2D,2E, 2F and 2G Complete by Week of May 24, 2010

Task 3: Prepare Modeling Report
3A: Draft Report Submit by Week of June 21, 2010
3B: Public Meeting Complete by Week of June 14, 2010

Project Task Descriptions

Brief summaries of the work to be performed and the deliverable products for each task are outlined below.

Task 1: Quality Assurance Project Plan (QAPP)

Using guidance provided by the U.S. Environmental Protection Agency for development of QAPP documents for modeling projects (USEPA, 2002), Dynamic Solutions has developed this QAPP for the Lake Thunderbird hydrodynamic and water quality model. This QAPP presents our approach for (a) ensuring that data sets that will be used for the lake modeling analyses meet quality criteria established for the project and (b) demonstrating the technical credibility of our selected model framework and its application for the determination of a watershed management plan for Lake Thunderbird. We have developed this QAPP to address the QA/QC procedures related to the evaluation of existing data sets, compilation of model input data, the selection of key model parameters and coefficients, and methods used for calibration of the Lake Thunderbird model framework.

Task 1 Deliverables: Dynamic Solutions will submit a Draft QAPP to DEQ within one month of receiving notice to proceed with work. Dynamic Solutions will submit a final QAPP for EPA approval after receiving comments from DEQ and EPA Region 6 on the draft submittal. The goal is to obtain EPA approval for the QAPP during the week of April 12, 2010.

Task 2: Water Quality Modeling

Dynamic Solutions will execute seven (7) sub-tasks as part of the water quality model development task. The specific activities and deliverables associated with these tasks are summarized briefly in the sub-task sections below.

Sub-Task 2A- Data Compilation and Data Inventory

The data necessary to construct the EFDC lake model will be compiled and the completeness of the data will be evaluated. Data sources will include:

- Data from the DEQ HSPF watershed model (QAPP included as Attachment #2)
- Routine lake and tributary monitoring by Oklahoma Water Resources Board (OWRB),
- Little River streamflow monitoring by the USGS at station 07230000 downstream of Lake Thunderbird,
- Lake level and storage volume monitoring by the USGS in cooperation with the Central Oklahoma Master Conservancy District (COMCD) and the U.S. Army Corps of Engineers (USCOE),
- Climatological data from the Oklahoma Mesonet network from station NRMN at Norman, OK,
- Water supply withdrawal data from COMCD,
- Water quality data from EPA STORET,
- Water quality samples collected by OWRB during the Oklahoma's Beneficial Use Monitoring Program (BUMP) October 2006 through June 2007,
- Water quality samples collected during the intensive surveys in Lake Thunderbird conducted by OWRB from April 2008 through April 2009,
- Bathymetric data collected by OWRB in June 2001 to map Lake Thunderbird, and
- Topographic NED 10-meter resolution data available from USGS for the Little River watershed.

Model calibration will be performed for a one-year period using data collected by OWRB during the intensive surveys from April 2008 through April 2009. The QAPP prepared by OWRB for the 2008-2009 intensive survey (OWRB, 2008b) is included in this modeling QAPP as Attachment #1. Section B9 presents details related to the data sets that will be used to develop the EFDC model of Lake Thunderbird. Details given in Section B9 include a discussion of the references for the secondary data sources, our criteria for selection of specific data sets, the intended uses of these data sets and any known limitations related to the data sets.

Sub-Task 2B- Model Setup

Dynamic Solutions will use grid generation software (Delft, 2007) to construct a 3D computational grid based on compiled shoreline, topographic and bathymetric data for the lake. Topgraphic data will be obtained from the USGS NED 10-meter resolution elevation data set for the watershed. Shoreline and bathymetric data will be obtained from the OWRB (2001) hydrographic survey of Lake Thunderbird. Using data collected by OWRB during the intensive survey of 2008-2009, initial conditions for the lake model will be assigned based on the spatial distribution of water quality variables in April 2008 at the beginning of the model calibration period. The HSPF watershed model that will be developed by DEQ for this project will provide the external boundary condition inputs for streamflow, water temperature and water quality loading of Total Suspended Solids (TSS), total organic carbon, dissolved organic carbon, dissolved oxygen, nitrogen (organic-N; ammonia-N and nitrate + nitrite-N) and phosphorus (total -P and dissolved-P) for input to the EFDC lake model. Since it is thought that the impairments are related to watershed loading, the development of accurate stream flow and water quality boundary concentrations with the HSPF model will be a critical element for the successful calibration of the lake model. Time series boundary condition data sets needed for input to the lake model include: watershed distributed runoff and tributary inflows; lake outflows, water supply withdrawals from the lake and atmospheric deposition of nutrients. Watershed distributed runoff and tributary inflows will be obtained from the results generated by the DEQ HSPF watershed model. Lake outflow data will be obtained from the U.S. Army Corps of Engineers for Lake Thunderbird (designated by the USCOE as NRM02). Water supply withdrawal data will be obtained from the COMCD. Atmospheric deposition of nutrients data will be obtained from the Clean Air Status and Trends Network (CASTNET) Station CHE185 (Cherokee Nation) and the National Atmospheric Deposition Program (NADP) for Station OK17 which is located nearest to Lake Thunderbird. External climatological time series data sets obtained from Oklahoma Mesonet for station NRMN at Norman, OK will be assigned to describe atmospheric forcing for dry and wet bulb temperature; relative humidity, barometric pressure, cloud cover and incident solar radiation, and wind speed and direction.

Sub-Task 2C- Linkage of HSPF Watershed Model Results for Input to EFDC Lake Model

Dynamic Solutions will prepare a data linkage between the DEQ developed HSPF watershed runoff model and the Dynamic Solutions developed EFDC lake model. The HSPF results will be used to assign the external boundary conditions for input to the EFDC lake model. The HSPF model will be developed by DEQ to provide the EFDC lake model with flow, water temperature, TSS, dissolved oxygen, total organic carbon, dissolved organic carbon, organic nitrogen, total phosphorus, dissolved phosphorus, ammonia, and nitrate + nitrite. A separate QAPP prepared by DEQ for the HSPF watershed model (DEQ, 2010) is included with this QAPP for the EFDC lake model as Attachment #2.The Dynamic Solutions Project Leader will coordinate closely with the DEQ Project Manager to ensure that the state variables modeled and the results files generated by the HSPF model are consistent with the Dynamic Solutions requirements for the HSPF-EFDC linkage program.

Sub-Task 2D- Hydrodynamic and Water Quality Model Calibration

The one-year calibration of the EFDC lake model will be performed using the intensive survey data collected by OWRB from April 2008 through April 2009. In calibrating the hydrodynamic, sediment transport and the water quality model, we will first assess the accuracy of external flows, loadings and forcing functions in relation to the preliminary lake model results. We will then direct our attention to adjusting various kinetic coefficients to improve model performance. Kinetic coefficients for the sediment transport, water quality model and the sediment flux model will initially be taken from the existing literature for EFDC (Park et al., 1995; Ji, 2008) and the sediment flux model (Di Toro, 2000) as well as the kinetic coefficients assigned by Dynamic Solutions for our previously developed EFDC models of Tenkiller Ferry Lake (DSLLC, 2006; QAPP QTRAK #06-182) and Wister Lake (DSLLC, 2008; QAPP QTRAK # 08-231). Model coefficients will be adjusted, as needed, within reasonable ranges of reported values, to achieve calibration of the Lake Thunderbird model to the observed 2008-2009 data set.

Calibration of the lake model will be accomplished by comparison of model results to observed data extracted from grid cells matching specific station locations in Lake Thunderbird (Figure A-3 for station locations). Model-data comparisons will be presented for water temperature, salinity (conductivity), TSS, dissolved oxygen, nutrients (N, P), algae biomass as chlorophyll-*a* and organic carbon. Model variables will be displayed as (a) time series plots to show surface layer and near bottom layer results; (b) vertical profiles for selected time snapshots matching sampling dates; and (c) spatial maps of surface layer and bottom layer results for selected time snapshots and/or animation of simulation results as AVI files. A discussion of model performance criteria and how the criteria will be used for the evaluation of model calibration results is presented in Section A7 Performance and Acceptance Criteria.

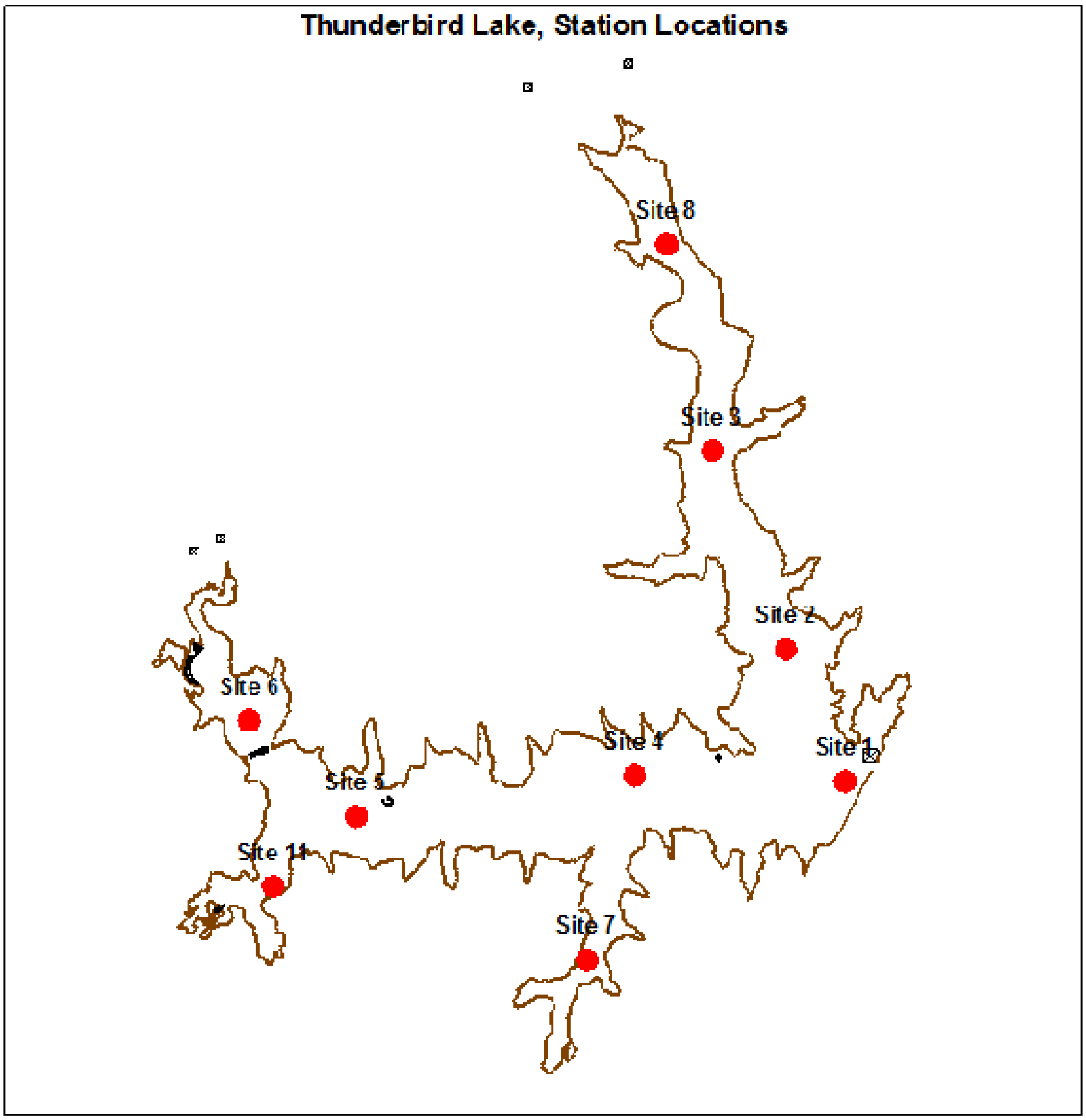

Figure A-3: Water Quality Monitoring Station Locations for Lake Thunderbird.

Sub-Task 2E- Water Quality Targets

In addition to the display of model-data results as described above, model results will also be displayed for comparison to water quality targets for dissolved oxygen, anoxic volume of the lake, chlorophyll-*a*, and Carlson's (1977) TSI.

Sub-Task 2F- Evaluation of Load Reductions for Nutrients and Sediments

The response of the EFDC lake model to reductions in external loading of nutrients, sediment and organic carbon will be determined by systematically reducing external watershed loads over a range of simple percentage reductions from 50% to 95%. The water quality response of the lake model to the systematic changes in external loads will be evaluated in terms of compliance with water quality targets for dissolved oxygen, the anoxic volume of the lake, TSI, and algae biomass as chlorophyll-*a*. Since the EFDC model is not designed to simulate turbidity as a state variable, a direct comparison of model results to the water quality target of 25 NTU for turbidity cannot be made. The EFDC lake model will, however, simulate the components of turbidity as total suspended solids (TSS), non-living particulate organic matter, and algae biomass. The model results for these constituents will then be used to simulate light attenuation in the water column and secchi disk depth as an indicator of water clarity.

The watershed-based load reduction scenario data will then be used by DEQ to identify the set of BMP's within the drainage basin that can be expected to reduce runoff loading from the watershed to improve water quality conditions in Lake Thunderbird. Based on the results obtained with the EFDC lake model, Dynamic Solutions will be responsible for determining the overall percent reductions needed at the inlet locations from the watershed to the lake for total nitrogen, total phosphorus, total organic carbon and TSS to meet in-lake water quality targets. Based on the load reductions determined with the EFDC model, DEQ will be responsible for (a) specifying appropriate watershed BMP strategies; (b) representing those BMP strategies in the HSPF model; and (c) running the HSPF model to simulate the BMP-based changes in external loads from the watershed to the lake. Dynamic Solutions will then link the BMP-based HSPF results for input to the EFDC lake model and perform one final EFDC run to simulate the response of the lake to the BMP-based watershed load reductions generated by DEQ with the HSPF model.

Sub-Task 2G- Evaluation of In-Lake Mitigation Alternatives

The calibrated EFDC lake model will also be used to provide the technical basis for recommendations for in-lake remediation strategies to improve water quality conditions within Lake Thunderbird. If, after discussions between the DEQ Project Manager and the Dynamic Solutions Project Leader, it is determined that an in-lake remediation strategy can be represented with the EFDC model, then Dynamic Solutions will conduct up to three (3) EFDC model runs to simulate in-lake remediation strategies recommended by stakeholders for the lake. DEQ will be responsible for providing data needed to represent a mitigation strategy and specifying the details of how each in-lake strategy might be represented in the lake model. Dynamic Solutions will be responsible for model setup and model execution to represent and evaluate the water quality impacts of each in-lake mitigation strategy.

Task 2 Deliverables: Dynamic Solutions will complete development of the model framework and initial model setup (Sub-Tasks 2A, 2B and 2C) within two (2) months of receiving notice to proceed. In order to complete calibration of the lake model and determination of required load reductions before June 30, 2010, DEQ must provide Dynamic Solutions with completed HSPF watershed model results for flow, water temperature TSS, nutrients (N, P) and organic carbon by the week of April 26, 2010. Dynamic Solutions will then be able to complete model calibration, simulation of loading reduction runs and in-lake mitigation strategies (Sub-Tasks 2D, 2E, 2F and 2G) within four (4) months of receiving notice to proceed.

Task 3: Prepare Modeling Report

Sub-Task 3A- Draft and Final Reports

Draft and final technical reports will be submitted as project deliverables to document data sources, model components and the development and calibration of the EFDC hydrodynamic and water quality model of Lake Thunderbird. The reports will include an executive summary, overview of the EFDC model, summary of data sources and data used in development of the lake model, calibration techniques and model results presented in both narrative and graphical form. Finally, the technical report will include a discussion of the methodology used, and the results obtained, to determine the watershed load reductions and in-lake mitigation strategies needed to achieve compliance with the water quality targets for Lake Thunderbird.

Sub-Task 3B- Public Meeting

In addition to submittal of draft and final technical reports for the project, the Dynamic Solutions Project Leader will travel to Oklahoma to participate in one (1) public meeting to present the findings of our lake modeling study to stakeholders. Dynamic Solutions will provide technical, editorial and graphic support to DEQ for the public meeting to prepare presentations describing our modeling approach and/or fact sheets to present the key issues/findings related to the model framework and the determination of the pollutant load reductions needed to attain compliance with water quality targets for the lake.

Task 3 Deliverable: Dynamic Solutions will provide a draft technical report to DEQ within five (5) months of receiving notice to proceed.

A7 QUALITY OBJECTIVES AND CRITERIA

Data Quality Objectives

Lake Thunderbird has been studied extensively over many years by Oklahoma state agencies (OWRB, 2003, 2004, 2005, 2006; 2008a) and by academic investigators (e.g., Gross and Pfiester, 1988). The data from these previous studies is thought to be reliable, and on the basis of that information and the professional judgment of OWRB and DEQ, OWRB initiated an intensive survey during a one-year period beginning in April 2008 through April 2009. The data sets were collected to supplement the available historical database to develop a linked surface water model framework based on the HSPF watershed model and the EFDC hydrodynamic and water quality model for the lake. The calibrated HSPF-EFDC model framework will be used for the determination of load reductions for constituents associated with water quality targets for dissolved oxygen, turbidity, nutrients and algae biomass that have been established for Lake Thunderbird.

Data Quality Objectives (DQOs) are quantitative and qualitative statements that clarify the intended use of data, define the types of data needed to support a decision, identify the conditions under which the data should be collected, and specify tolerable limits on the probability of making a decision error because of uncertainty in the data. Data of known and documented quality are essential components of the success of a watershed, hydrodynamic and water quality modeling study because the models, in turn, generate data used to support the decision-making process for the lake watershed plan. Field monitoring programs conducted to provide the observed data used in the development of the watershed runoff model (HSPF) and the Lake Thunderbird hydrodynamic and water quality (EFDC) models were implemented using recognized QA/QC procedures for sample collection and analytical chemistry. No new observed data will be collected as part of this project. All data used in the modeling analyses will be reviewed for quality and consistency with other relevant data to determine if the observed data used for model development is, in fact, representative of the watershed and Lake Thunderbird. All QA/QC information available for the data sets will be reviewed and documented.

The types of data used to develop the models, along with the sources, intended use and any relevant QA/QC documentation are detailed in Table B-1 in Section B9 of this document. A brief summary of the data requirements, and the relevant time frame and spatial domain, for development of the hydrodynamic and water quality model of Lake Thunderbird is given below.

Categories of data that will be compiled to develop the EFDC hydrodynamic model of Lake Thunderbird include: topography, shoreline and bathymetry; atmospheric forcing; and upstream boundary inflows from the watershed for flow and water temperature. Additional categories of data needed to develop the EFDC sediment transport and water quality model of Lake Thunderbird include: ambient water quality (e.g., dissolved oxygen, organic carbon, nutrients, suspended solids); sediment bed properties (e.g., particle size; carbon and nutrient content) and sediment-water benthic fluxes of dissolved oxygen and nutrients. Spatial data (shoreline, topography and bathymetry) will be compiled for the Lake Thunderbird model domain as shown in Figure A-3. The upstream boundary and in-lake data sets are data sets collected as time series data at specific station locations within the model domain. The numerous references to time series data sets in this QAPP document refer to multiple time series data sets that have been collected (or simulated by the HSPF watershed model) at multiple watershed inflow locations or in-lake station locations within the spatial domain of the watershed and lake models.

There is no ultimate decision error associated with this project. Decision errors related to the use of historical or regional background data can be lumped into apparent analytical results by model calibration and validation. Uncertainties in flow, climate, assumptions about land use, permeability, fate-and-transport, etc., are all reflected by the error associated with analytical measurements when watershed, hydrodynamic and water quality models are calibrated to historical data sets.

Performance and Acceptance Criteria

Model performance will be evaluated to determine the endpoints for model calibration using a "weight of evidence" approach that has been adopted for many water quality model studies (Donigian, 1982; 2000). Our "weight of evidence" approach includes the following steps: (a) visual inspection of plots of model results compared to observed data sets (e.g., station time series or vertical profiles); and (b) analysis of model-data performance statistics. The "weight of evidence" approach recognizes that, as a numerical model approximation of Lake Thunderbird, perfect agreement between observed data and model results is not expected and is not specified as a performance criterion for model calibration. Model performance statistics will be used, not as absolute criteria for acceptance of the lake model, but rather, as guidelines to supplement our visual inspection of model-data plots to determine appropriate endpoints for calibration of the Lake Thunderbird model. The "weight of evidence" approach thus acknowledges the approximate nature of a surface water model and the inherent uncertainties in both input data and observed data (Oreskes et al., 1994).

The focus of this portion of Section A7 is to specify model performance criteria. This is the basis by which judgments will be made on whether the EFDC hydrodynamic and water quality model results for Lake Thunderbird are sufficient and adequate to support watershed management planning decisions. Model performance criteria, sometimes referred to as calibration and/or validation criteria, have been contentious topics for more than 20 years (Donigian et al. 1982; Donigian, 2000; Thomann, 1982; Oreskes et al., 1994). Despite a lack of consensus, surface water models are being applied, and their results are being used, for water quality assessment and regulatory purposes, including the development of TMDL's, load allocations and evaluations of management strategies. A 'weight of evidence' approach is most widely used and accepted when models are examined and judged for acceptance for these purposes. Consequently, an approach based on the 'weight of evidence' concept that embodies the following principles, will be adopted for this study:

- Because models are approximations of natural systems, exact duplication of observed data is not a performance criterion. The model calibration process will measure, through comparability goals, the ability of the hydrodynamic and water quality model to simulate observed data sets.
- No single procedure or statistic is widely accepted as measuring, nor capable of establishing, acceptable model performance; thus qualitative graphical comparisons of observed data and model results will be used to provide sufficient evidence to weight the decision of model acceptance or rejection
- All model and observed data comparisons must recognize, either qualitatively or quantitatively, the inherent errors and uncertainty in both the model and the measurements of the observed data sets. These errors and uncertainties will be documented, where possible, as part of this modeling study.

In evaluating the results obtained with the EFDC hydrodynamic model, a Relative RMS Error performance measure of $\pm 20\%$ is adopted for evaluation of the comparison of the model predicted results and observed measurements of water surface elevation of the lake. For the hydrographic state variables simulated with the EFDC hydrodynamic model, a Relative RMS Error performance measure of $\pm 50\%$ is adopted for evaluation of the comparison of the predicted results and observed measurements of salinity and water temperature. For the water quality state variables simulated with the EFDC water quality model, a Relative RMS Error performance measure of $\pm 20\%$ is adopted for dissolved oxygen; $\pm 50\%$ for nutrients and suspended solids; and $\pm 100\%$ for algal biomass for the evaluation of the comparison of the predicted results and observed water quality measurements for model calibration. These targets for hydrodynamic, sediment transport and water quality model performance are consistent with the range of model performance targets recommended for the HSPF watershed model (Donigian, 2000).

The Relative RMS Error, expressed as a percentage, is computed as the ratio of the RMS Error to the observed range of each water quality constituent (Blumberg et al., 1999; Ji, 2008). The equations for the RMS Error and the Relative RMS Error are given below:

$$RMS\_Error = \sqrt{\frac{1}{N}\Sigma(O-P)^2}$$

$$\mathrm{Re}lative\_RMS\_Error = \frac{RMS\_Error}{(O_{range})} x100$$

where:
N is the number of paired records of observed measurements and model results
O is the observed water quality measurement
P is the predicted model result
O_{range} is the range of observed from maximum to minimum values

Given the lack of a general consensus for defining quantitative model performance criteria, the inherent errors in input and observed data, and the approximate nature of model formulations, *absolute* criteria for model acceptance or rejection are not appropriate for studies such as the development of a lake model for Lake Thunderbird. The relative RMS errors presented above will be used as targets, but not as rigid criteria for rejection or acceptance of model results, for the performance evaluation of the calibration of the EFDC hydrodynamic and water quality model of Lake Thunderbird.

Any model performance comparison of model results versus observed measurement yielding differences greater than the relative RMS errors listed above will trigger a re-evaluation of all data used to construct the lake model to determine if (a) the input data is valid and needs to be revised or (b) the observed data sets are valid. If the input data requires revision, or if the observed data sets require modification, then the model input files and/or observed data files will be revised, as needed, and the model re-run with the objective of achieving an acceptable comparison of model vs. observed data. Observed data sets may require modification, if, for example, a reevaluation of the observed data for water temperature indicated that the measured units as F had not been converted, as needed, to the EFDC units of C. A justification will be documented if data revisions are necessary.

If performance measures of the lake model do not meet the project's requirements for DQOs as outlined above, the input data and the observed data sets used to construct the model and the calibration assignment of adjustable model parameters will be carefully reviewed and re-evaluated to determine why model performance criteria were not achieved. However, the model calibration will not necessarily be considered unacceptable if model results fall outside the performance criteria. Decisions will be made jointly by the Dynamic Solutions Project Manager and Project Leader and the DEQ Project Manager about (a) the validity of the input data and observed data used to construct the models (b) the steps needed to complete development of the model to achieve satisfactory performance. If satisfactory performance is not achieved, then a discussion of the possible explanations for the poor performance of the model will be presented and discussed in the technical report prepared for this study.

External loading rates of TSS, TOC and nutrients (N, P), generated by the HSPF watershed model for catchments defined by tributaries and distributed runoff, will be linked for input to the EFDC lake model as daily time series data sets. The response of the calibrated EFDC lake model to reductions in external loading of nutrients, sediment and organic carbon will be determined by systematically reducing external watershed loads over a range of simple percentage reductions from 50% to 95%. The water quality response of the lake model to the changes in external loads will be evaluated in terms of compliance with water quality targets for dissolved oxygen, the anoxic volume of the lake, TSI, and algae biomass as chlorophyll-*a*. Since the EFDC model is not designed to simulate turbidity as a state variable, a direct comparison of model results to the water quality target of 25 NTU for turbidity cannot be made. The EFDC lake model will, however, simulate the components of turbidity as total suspended solids (TSS), non-living particulate organic matter, and algae biomass. The model results for these constituents will then be used to simulate light attenuation in the water column and simulated secchi disk depth as indicators of water clarity.

Using the HSPF "baseline calibration" results, HSPF-EFDC linkage software and the EFDC lake model, Dynamic Solutions will systematically apply load reduction factors for TSS, organic carbon and nutrients (N, P) at the inflow locations from the watershed to the lake to identify a load reduction scenario that is expected to achieve compliance with water quality targets. Based on the known efficient numerical scheme known as the "binary" or "bisection" search method (Press et al., 1992), the search for a load reduction scenario will initially be defined by a 50% reduction of the loading used for the model calibration. If the water quality response to this load is in compliance with a 50% reduction, then the load reduction factor will be decreased to 25%. More likely, however, if the water quality response is not in compliance with all the water quality targets with a 50% reduction scenario, then the load reduction factor will be increased iteratively from (a) 50% to 75%; (b) 75% to 85% and (c) 85% to 95% until compliance is either achieved or it is demonstrated that even 95% removal of existing watershed loading may not achieve the water quality targets. Starting with the 50% reduction scenario, a maximum of up to four model runs may be performed to determine the required load reduction factors. For the highest load reduction scenario where the lake water quality targets are still not met, the lake model will then be applied for a series of no more than four sequential "re-start" runs to determine (a) the long-term "spin-up" time needed for the sediment flux model to attain a new quasi-equilibrium condition between the water column and sediment bed based on the reduced external load scenario from the watershed, (b) the effect of internal nutrient loads from sediment on the timeframe for in-lake water quality improvement, and (c) if the long-term "spin-up" changes to the sediment-water flux of nutrients then results in attainment of lake water quality targets. Since model calibration will include the one-year period from April 2008 to April 2009, four sequential "spin-up" runs should provide a sufficient time scale to attain new equilibrium conditions once external loads are reduced from the watershed.

Using the results obtained from the systematic reduction of loads from the watershed, the watershed-based load reduction scenario data that meets the water quality targets for the lake will then be used by DEQ to identify the set of BMP's within the drainage basin expected to reduce runoff loading from the watershed to improve water quality conditions in Lake Thunderbird. Based on the results obtained with the EFDC lake model, Dynamic Solutions will be responsible for determining the overall percent reductions needed at the inlet locations from the watershed to the lake for total nitrogen, total phosphorus, total organic carbon and TSS to meet in-lake water quality targets. Based on the load reductions determined with the EFDC lake model, DEQ will be responsible for (a) specifying appropriate watershed BMP strategies; (b) representing those BMP strategies in the HSPF model; and (c) running the HSPF model to simulate the BMP-based changes in external loads from the watershed to the lake. Dynamic Solutions will then link the BMP-based HSPF results for input to the EFDC lake model and perform one (1) final EFDC run to simulate the response of the lake to the BMP-based watershed load reductions generated by DEQ with the HSPF model.

Data Requirements and Criteria for Data Completeness and Representativeness

Table B-1 in Section B9 identifies the categories of data needed to develop the EFDC hydrodynamic model of Lake Thunderbird. A detailed discussion of the available data sets including the criteria used for acceptance of the data sets is presented in Section B9 of this QAPP. Water quality constituents included in the EFDC hydrodynamic, sediment transport and water quality model are listed in Table A-1. Units of g/m^3 shown in the table are equivalent to mg/L. State variables and fluxes for the EFDC sediment flux model are given in Table A-2.

Table A-1
State Variables for EFDC Hydrodynamic, Sediment Transport, and Water Quality Model

Code	EFDC State Variable	EFDC Parameter ID	EFDC Units	Used in Model
NA	Water Surface Elevation	WS	meters	Yes
NA	Salinity	SAL	ppt	Yes

Code	EFDC State Variable	EFDC Parameter ID	EFDC Units	Used in Model
NA	Water Temperature	TEM	°C	Yes
NA	Inorganic Cohesive Sediments	COH	mg/L	Yes
1	Cyanobacteria(blue-green algae)	CHC	mg C/L	No
2	Diatoms (algae)	CHD	mg C/L	No
3	Green Algae	CHG	mg C/L	Yes
4	Refractory Particulate Organic Carbon	RPOC	mg C/L	Yes
5	Labile Particulate Organic Carbon	LPOC	mg C/L	Yes
6	Dissolved Organic Carbon	DOC	mg C/L	Yes
7	Refractory Particulate Organic Phosphorus	RPOP	mg P/L	Yes
8	Labile Particulate Organic Phosphorus	LPOP	mg P/L	Yes
9	Dissolved Organic Phosphorus	DOP	mg P/L	Yes
10	Total Phosphate	TPO4	mg P/L	Yes
11	Refractory Particulate Organic Nitrogen	RPON	mg P/L	Yes
12	Labile Particulate Organic Nitrogen	LPON	mg N/L	Yes
13	Dissolved Organic Nitrogen	DON	mg N/L	Yes
14	Ammonia Nitrogen	NHX	mg N/L	Yes
15	Nitrate Nitrogen	NOX	mg N/L	Yes
16	Particulate Biogenic Silica	SUU	mg Si/L	No
17	Dissolved Available Silica	SAA	mg Si/L	No
18	Chemical Oxygen Demand	COD	mg O_2/L	Yes
19	Dissolved Oxygen	DOX	mg O_2/L	Yes
20	Total Active Metals	TAM	mol/m^3	No
21	Fecal Coliform	FCB	mpn/100 mL	No

Table A-2: EFDC Sediment Flux Model State Variables and Flux Terms

No.	Name	Bed Layer	Units	Activated
1	POC-G1	Layer-2	g/m^3	Yes
2	POC-G2	Layer-2	g/m^3	Yes
3	POC-G3	Layer-2	g/m^3	Yes
4	PON-G1	Layer-2	g/m^3	Yes
5	PON-G2	Layer-2	g/m^3	Yes
6	PON-G3	Layer-2	g/m^3	Yes
7	POP-G1	Layer-2	g/m^3	Yes
8	POP-G2	Layer-2	g/m^3	Yes
9	POP-G3	Layer-2	g/m^3	Yes
10	Partic-Biogenic-Silica	Layer-2	g/m^3	No
11	Sulfide/Methane	Layer-1	g/m^3	Yes
12	Sulfide/Methane	Layer-2	g/m^3	Yes
13	Ammonia-N	Layer-1	g/m^3	Yes
14	Ammonia-N	Layer-2	g/m^3	Yes

No.	Name	Bed Layer	Units	Activated
15	Nitrate-N	Layer-1	g/m^3	Yes
16	Nitrate-N	Layer-2	g/m^3	Yes
17	Phosphate-P	Layer-1	g/m^3	Yes
18	Phosphate-P	Layer-2	g/m^3	Yes
19	Available-Silica	Layer-1	g/m^3	No
20	Available-Silica	Layer-2	g/m^3	No
21	Ammonia-N-Flux	Layer-1	g/m^2-day	Yes
22	Nitrate-N-Flux	Layer-1	g/m^2-day	Yes
23	Phosphate-P-Flux	Layer-1	g/m^2-day	Yes
24	Silica Flux	Layer-1	g/m^2-day	No
25	SOD Flux	Layer-1	g/m^2-day	Yes
26	COD Flux	Layer-1	g/m^2-day	Yes
27	Bed Temperature	Layer-1	Deg-C	Yes

* SOD is Sediment Oxygen Demand
**COD is Chemical Oxygen Demand

Input data for the EFDC water column state variables will be assigned as (a) initial conditions based on observed water quality data collected in April 2008 at stations located within the lake (Figure A-3) and (b) external boundary condition data sets generated by linkage of time series data sets derived from the DEQ-developed HSPF watershed model results. Initial conditions and boundary conditions for the cohesive and non-cohesive classes of solids in the simplified sediment transport model will be based on fractional splits of TSS data obtained from monitoring station observations and/or time series results of the HSPF watershed model. For the Lake Thunderbird model, 100% of the TSS will be assigned as a single class of cohesive solids. This is an appropriate assumption for the sediment transport model since silts and clays represent most of the particulate matter that remain in suspension and contribute to turbidity in the lake. Although the EFDC model is coded to allow the specification of up to three different functional species groups of algae, the algae data that was collected by OWRB during 2008-2009 describes only total algae biomass measured as chlorophyll-*a*. Species level taxonomic data is not available for the 2008-2009 OWRB data set to split the total biomass measured as chlorophyll into different species groups such as diatoms, dinoflagellates, cyanobacteria (blue-green) or chlorophytes (green) algae. Initial conditions and boundary conditions for the algae state variables of the water quality model will therefore be simplified in the Lake Thunderbird model based on the representation of all algae as a single functional group of phytoplankton. Observed measurements from lake station data for algae biomass (as chlorophyll-*a*) will be used to assign algal biomass to the "Green Algae" group.

Dynamic Solutions has developed custom software to provide a systematic automated approach for the linkage of flow boundary conditions derived from HSPF results for flow and pollutant loads and other flow boundary conditions derived from monitoring station data sets to provide boundary condition input files formatted for input to the EFDC model. Linkage of the results generated by the HSPF model for input to EFDC requires that HSPF be properly structured to provide the time series data needed for input to the EFDC model. In addition to the specific state variables that will be setup for the HSPF model by DEQ, the output results from HSPF must be written using the standard *.PLT file tabular column format available in HSPF. In the HSPF model, organic matter is represented as labile organic matter (carbonaceous biochemical oxygen demand ultimate (CBOD-ultimate) and refractory organic matter (Total Organic Carbon, Total Organic Nitrogen and Total Organic Phosphorus). Linkage of state variables for streamflow, water temperature, suspended solids, dissolved oxygen, NH3 (ammonia), NO2 (nitrite) + NO3 (nitrate), and PO4 (phosphate) from HSPF to EFDC is straightforward. For organic matter as C (carbon), N (nitrogen), and P (phosphorus), however, the correct linkage of HSPF results for input to EFDC requires an understanding of what HSPF is representing with labile/refractory organic matter state variables so that the HSPF results can be correctly "mapped" for input to EFDC. Mapping of labile organic matter as CBOD to organic C, N, P in EFDC is accomplished by defining stoichiometric ratios for O2/C, C/N and C/P. Fractional splits of labile and refractory organic matter simulated by HSPF are then assigned to derive dissolved; and particulate labile/refractory components of total organic carbon, total organic nitrogen and total organic phosphorus for input to EFDC.

During the interim period while DEQ is completing development and calibration of the HSPF model, Dynamic Solutions will use the observed stream monitoring data collected by OWRB during 2008-2009 to setup a preliminary version of the EFDC hydrodynamic and water quality model. When DEQ completes the HSPF watershed model and provides the final watershed model calibration results to Dynamic Solutions, Dynamic Solutions will then update the preliminary EFDC model setup with the calibrated HSPF results for final calibration of the lake model.

A8 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

Dynamic Solutions personnel, all of whom hold graduate degrees from universities well known for excellence and leadership in surface water modeling, are internationally recognized as experts in the field of hydrodynamic and water quality modeling. Dynamic Solutions personnel all have 20+ years of professional experience developing, modifying and applying surface water models in numerous types of water bodies. Since 1999, Dynamic Solutions personnel have used EFDC and EFDC_Explorer to develop multi-dimensional hydrodynamic, sediment transport, toxic chemical and water quality models in rivers, lakes, estuaries and coastal waters. In addition to software development, database design, statistical analysis and numerical modeling skills, Dynamic Solutions personnel also possess extensive field experience from academic research cruises and hydrographic/water quality surveys that contributes significantly to the success of our complex modeling studies.

No special training or certification is required for participants in this project beyond the already high degree of academic training and professional experience in environmental engineering, hydrology, fluid dynamics, aquatic ecology and chemistry, surface water modeling, software development, mathematics, statistics or other sciences that they have obtained in order to fulfill job requirements commensurate with their current assignments. As described above, Dynamic Solutions personnel can provide the high level of technical expertise required to successfully develop a calibrated hydrodynamic and water quality model of Lake Thunderbird.

A9 DOCUMENTATION AND RECORDS

Dynamic Solutions is responsible for the development of the hydrodynamic and water quality model of Lake Thunderbird for this project. The DEQ Project Manager, as the end user of the hydrodynamic and water quality model results generated for this project, will be provided the hydrodynamic and water quality model results for determination of the load allocation for controlling pollutant loading to Lake Thunderbird to meet water quality targets. The Dynamic Solutions Project Leader will assist the Dynamic Solutions QAO in updating and distributing copies of the current QAPP for this project to the DEQ Project Manager.

Information to be Included in Reporting Packages

The project consists of the development of new models for watershed runoff (HSPF), hydrodynamics and water quality (EFDC) for Lake Thunderbird. The DEQ is responsible for the development and calibration of the HSPF watershed runoff model. Dynamic Solutions is responsible for the development and calibration of the EFDC hydrodynamic and water quality model of the lake. The following general forms of records needed by Dynamic Solutions for development of the lake model include:

- An inventory of data input parameters for EFDC, including those parameters used for model calibration analyses;
- All hydrodynamic and water quality model input files as (a) original reformatted data sets and (b) EFDC input format;
- Output results generated by the EFDC hydrodynamic and water quality model;
- Tables of model performance statistics computed for the EFDC hydrodynamic and water quality model;
- Compiled executable files for the versions of EFDC and EFDC_Explorer used by Dynamic Solutions for application to Lake Thunderbird;
- Monthly progress reports;
- Draft and final technical reports to document data sources, model development, calibration of model results and evaluation of the effectiveness of watershed load reductions and in-lake mitigation strategies on improving water quality conditions in the lake.
- Technical, editorial and graphic support to DEQ for the public meeting of Stakeholders to prepare presentations describing our modeling approach and/or fact sheets to present the key issues/findings related to the model framework and the determination of the pollutant load reductions needed to attain compliance with water quality targets for the lake.

Draft and final technical reports will be submitted as project deliverables to document data sources, model components and the development and calibration of the EFDC hydrodynamic and water quality model of Lake Thunderbird. The lake model report will provide an overview of the key technical features of the hydrodynamic, sediment transport, water quality and sediment diagenesis models used for the Lake Thunderbird study. In addition, the lake model report will also include a discussion of procedures used for HSPF-EFDC linkage of the watershed model results as external boundary conditions, model calibration results, including relative error statistics to document model performance, and application of the lake model for determination of pollutant load reductions to attain compliance with water quality targets. The draft and final reports will include, but not be limited to, an executive summary, overview of the EFDC model, summary of data sources and data used in development of the lake model, calibration techniques and model results presented in both narrative and graphical form. Finally, the technical report will include a discussion of the methodology used, and the results obtained, to determine the watershed load reductions and in-lake mitigation strategies needed to achieve compliance with the water quality targets for Lake Thunderbird.

Dynamic Solutions will review, and address, one combined set of EPA Region 6, DEQ and stakeholder comments received on the draft technical report that we submit as a deliverable for the project. Comments may be received internally from EPA and DEQ and externally from stakeholders during the public comment period. Dynamic Solutions will discuss all substantive comments with the DEQ Project Manager, as needed, to decide on a course of action to best address the comments for incorporation into the final technical report.

Draft and final technical reports will be submitted to DEQ as electronic file copies of our reports. The final deliverables for the project will also include data files developed in connection with services provided under this contract effort. Electronic data files will include: (a) HSPF-EFDC linkage program executable files and input data files; (b) EFDC model executable file, input data files and observed data files used for model-data comparisons; (c) EFDC_Explorer setup and executable files; and (d) draft and final lake model reports. Electronic files will be provided to DEQ either on DVD(s), external removable hard drive media or by file transfer to the Dynamic Solutions FTP site.

In addition to submittal of draft and final technical reports for the project, Dynamic Solutions will also travel to Oklahoma to participate in one (1) public meeting to present the findings of our lake modeling study to stakeholders. Dynamic Solutions will provide technical, editorial and graphic support to DEQ for the public meeting to prepare presentations describing our modeling approach and/or fact sheets to present the key issues/findings related to the model framework and the determination of the pollutant load reductions needed to attain compliance with water quality targets for the lake.

Data Reporting Package Format and Documentation Control

The Dynamic Solutions Project Leader is responsible for retaining information and he will do so both in electronic and hardcopy formats. Records of the project will be maintained so that another person could duplicate the work performed for development of the Lake Thunderbird hydrodynamic and water quality model with a reasonable amount of effort. All files prepared for calibration of the hydrodynamic and water quality model will be transferred to the DEQ Project Manager in electronic format as EFDC input data sets in ASCII text files compiled for use in EFDC_Explorer pre- and post-processor software. As appropriate, other files, such as GIS shape files, Microsoft Excel spreadsheet files and Microsoft Word document files, related to the Lake Thunderbird project will also be posted on the Dynamic Solutions File Transfer Protocol (FTP) site for downloading by DEQ. The draft and final technical reports prepared for the project will include the following items: (a) identification and inventory of data sources used; (b) maps of the spatial domain and computational grid scheme of the EFDC model; (c) model vs. observed data comparisons of water quality constituents plotted as time series at selected station locations; (d) model vs. observed data comparisons of water quality constituents plotted as time averaged vertical profiles at selected stations of Lake Thunderbird; (e) summary of model performance statistics; (f) discussion of model results, including the results of load allocation runs and in-lake mitigation strategies. During the course of the project, all project related files are copied to backup media on a daily basis as files are either created or updated. Routine backup of project files is performed on a weekly basis. A hard drive of our network computer and large capacity external hard drives are both used as backup media for the project.

Data Reporting Package Archive and Retrieval

At the conclusion of the project, the source codes and executable files for EFDC and EFDC_Explorer, HSPF-EFDC linkage pre-processing software and post-processing software, original raw input data files and reformatted input data files, EFDC model results and project deliverables will be written to external portable hard drives with a Universal Serial Bus (USB) connection for storage at Dynamic Solutions in Knoxville, Tennessee. Once a project is completed, files will be archived on a portable external hard drive for permanent storage by Dynamic Solutions. Electronic files generated for a project that are archived on backup media will not be discarded by Dynamic Solutions after a given number of years. In addition to the electronic records of the project, which are the natural result of a computer modeling project, the Dynamic Solutions Project Leader will retain all working notes, modeling logs and results in hardcopy form. Three-ring binders and letter size file pockets will be used to organize modeling logs and other hard copy materials for ready access during the project as well as for the project archives.

SECTION B: MEASUREMENT AND DATA AQUISITION

B1 SAMPLING PROCESS DESIGN

NA – no new sampling data will be collected under this QAPP during this project.

B2 SAMPLING METHODS

NA – no new sampling data will be collected under this QAPP during this project.

B3 SAMPLE HANDLING AND CUSTODY

NA – no new sampling data will be collected under this QAPP during this project.

B4 ANALYTICAL METHODS

NA – no new sampling data will be collected under this QAPP during this project.

B5 QUALITY CONTROL

NA – no new sampling data will be collected under this QAPP during this project.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE

NA – no new sampling data will be collected under this QAPP during this project.

B7 INSTRUMENTATION/EQUIPMENT CALIBRATION AND FREQUENCY

NA – no new sampling data will be collected under this QAPP during this project.

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

NA – no new sampling data will be collected under this QAPP during this project.

B9 NON-DIRECT MEASUREMENTS (DATA ACQUISITION REQUIREMENTS)

Historical information, previously collected by federal, state and local agencies, will be used for development of the EFDC hydrodynamic and water quality model for Lake Thunderbird. Because there will not be any new sampling or measurements involved in this project, no new monitoring data will be generated for this study. Published reports, including electronic files, obtained from the DEQ, OWRB, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC), Oklahoma Mesonet climatological data, U.S. Army Corps of Engineers (USCOE), and the U.S. Geological Survey (USGS) will serve as the primary data sources for the project. Sampling requirements and procedures used by the OWRB and DEQ for the collection of water quality, bathymetry and hydrologic data in the Little River catalog unit (11090203) and in Lake Thunderbird are already documented by these agencies in separate Quality Assurance Project Plans for those data collection efforts. Because data collected by federal, state and local agencies has already been compiled and subjected to QA/QC procedures for field data collection, the numeric values of the data used for this hydrodynamic and water quality modeling project will be accepted at face value. However, the data will be evaluated based on comparisons among the data and between the project data and the data obtained from electronic databases. Evaluations based on comparisons of observed data sets include checks on the observed maximum and minimum ranges of water quality constituents and whether or not there are any outliers in the data sets that appear questionable and should be discarded. As discussed in Section C1 Assessments and Response Actions, Data Acquisition, one way outliers are identified by simple visual inspection of data plots and best professional judgment is based on knowledge of what is considered a reasonable range of values for a specific water quality constituent in a waterbody such as Lake Thunderbird. All readily available QA/QC information and metadata associated with non-direct data will be documented and referenced in the project archives.

Table B-1 summarizes the different types of data sets needed for construction of the EFDC lake model. The table also indicates the use of the data set and sources for the data sets that will be used for the project. A summary discussion of references for the secondary data sources, our criteria for selection of specific data sets, the intended uses of these data sets and any known limitations related to the data sets is presented for each of the Data Groups and Data Sets indicated in Table B-1.

Table B-1: Types of Data Used for EFDC Hydrodynamic and Water Quality Model

Data Group/Data Set	**Use of Data Set**	**Notes**	**Data Source**
Physical Domain			
Topography	Model grid	10-m resolution	USGS NED
Bathymetry	Model grid	2001 survey	OWRB
Shoreline	Model grid	2001 survey	OWRB
Watershed Loading			
Tributary Flow	boundary	Little R; Hog Creek etc	HSPF
Distributed Runoff	boundary	Nonpoint source	HSPF
Water Temp	boundary		HSPF
Salinity	boundary	Conductivity	OWRB
TSS	boundary	Suspended solids	HSPF
Oxygen	boundary		HSPF
Nutrients	boundary	Nitrogen, Phosphorus	HSPF
Organic carbon	boundary		HSPF
Algae	boundary	Chlorophyll-*a*	DSLLC (2006)
Atmospheric Deposition	boundary	Nutrients (N,P)	NADP&CASTNET
Flow Balance			
Tributary Flow	Hydrodynamics	Little R; Hog Creek etc	HSPF
Distributed Runoff	Hydrodynamics	Nonpoint source	HSPF
Withdrawals	Hydrodynamics	Public water supply	COMCD
Lake Storage	Hydrodynamics	Storage-elevation relation	Bureau Reclamation

Data Group/Data Set	**Use of Data Set**	**Notes**	**Data Source**
Lake Outflow	Hydrodynamics	Release at dam	USCOE
Lake Monitoring			
Water Temp	Calibration		OWRB
Salinity	Calibration	Conductivity	OWRB
TSS	Calibration	Suspended solids	OWRB
Oxygen	Calibration		OWRB
Nutrients	Calibration	Nitrogen, Phosphorus	OWRB
Organic carbon	Calibration		OWRB
Algae	Calibration	Chlorophyll-*a*	OWRB
Water Clarity	Calibration	Secchi depth; turbidity	OWRB
Sediment Bed			
Solids content	Sediment Transport	% dry weight solids	DSLLC (2006,2008)
Porosity	Sediment Transport	Dimensionless ratio	DSLLC (2006,2008)
Organic-C	Sediment Flux	% dry weight carbon	DSLLC (2006,2008)
Organic-N	Sediment Flux	% dry weight nitrogen	OWRB
Organic-P	Sediment Flux	% dry weight phosphorus	OWRB
Inorganic-N	Sediment Flux	Porewater NH3, NO3	DSLLC (2006,2008)
Inorganic-P	Sediment Flux	Porewater PO4	DSLLC (2006,2008)
Atmospheric Forcing			
Barometric pressure	hydrodynamics		Mesonet
Air Temp	hydrodynamics		Mesonet
Relative Humidity	hydrodynamics		Mesonet
Solar Radiation	hydrodynamics/WQ		Mesonet
Cloud Cover	hydrodynamics/WQ		Mesonet
Precipitation	hydrodynamics		Mesonet
Evaporation	hydrodynamics		Mesonet
Wind Speed/Dir.	hydrodynamics/WQ		Mesonet
	WQ is Water Quality		

Physical Domain

Data is needed to assign bottom elevations for the computational grid of the EFDC lake model. Elevation data that will be used includes bathymetry data for the lake and topography data for the watershed. OWRB collected the only known source of high-resolution bathymetry data in Lake Thunderbird in 2001. High-resolution (10-meter grid data) topographic data, obtained from the USGS NED for the Little River watershed (http://ned.usgs.gov), is preferable to the lower resolution 30-meter grid data for the purposes of building a computational grid of the lake. The shoreline data will be used to construct the computational grid for the model. The topography and bathymetry data sets will then be merged with the shoreline data set to assign bottom elevations for the computational grid cells of the lake model. There are no known limitations of these data sets.

Watershed Loading

Runoff flow, tributary flow and water quality concentration data will be used to specify the external flow-driven loading of water quality constituents for use as external boundary condition inputs to the EFDC lake model. The HSPF watershed model that will be developed by DEQ will be the only data source for all watershed flow and water quality concentration and load data sets used to develop the lake model. A QAPP for the HSPF watershed model is available from DEQ and is included with this QAPP as Attachment#2. In addition to the flow boundary conditions for the lake model, atmospheric deposition of nutrients is also included as an external source of nutrients for the lake model. Nutrient concentrations of rainfall (wet deposition) and nutrient loading rates for dry deposition will be obtained from the National Atmospheric Deposition Program (NADP) station located at Kessler Farm Field Laboratory in McClain County (OK17) and the Clean Air Status and Trends Network (CASTNET) station located at Cherokee Nation in Adair County (CHE188). URL addresses for these data sources are http://nadp.sws.uiuc.edu/ and http://www.epa.gov/castnet/. Rainfall data for wet deposition will be obtained from the Oklahoma Mesonet program for the station located at Norman (NRMN) that is closest to Lake Thunderbird (http://www.mesonet.org/). The primary limitation of the atmospheric deposition data is the sparse network of monitoring stations that are available to represent loading for a site-specific location such as Lake Thunderbird. The monitoring stations identified above are closest in proximity to Lake Thunderbird and will be used to assign rainfall, wet and dry deposition data for the lake model.

Flow Balance

Flow balance data is needed to simulate lake volume and lake elevation as a function of water flowing into and out of the lake over time. Water inflows to the lake include rainfall directly onto the lake surface, distributed runoff and tributary discharges. Rainfall data will be obtained from the Oklahoma Mesonet database as described above. Water inflow data will be obtained as output results from the DEQ HSPF model of the watershed. Public water supply withdrawal data from the lake is recorded by COMCD as outflows from the lake. The accuracy of the COMCD public water supply withdrawal, however, is not known at this time by DEQ. Records of outflow releases at the lake dam are available from the USCOE for Lake Thunderbird (Site NRM02) (http://www.swt-wc.usace.army.mil/THUN.lakepage.html). Hourly time series data for gage height and storage volume of the lake, in cooperation with the USCOE and COMCD, is available for downloading from the USGS (http://waterdata.usgs.gov/usa/nwis/) for Station 07229900. The relationship of lake storage and lake elevation, developed from the bathymetry data collected by OWRB in 2001, is used to construct a time series of lake elevation for comparison to the EFDC model results for calibration of the hydrodynamic model. Other than the unknown accuracy of the COMCD public water supply withdrawal data set, there are no known limitations of these flow balance data sets.

Lake Monitoring

Lake monitoring data is needed for (a) model setup of the initial conditions and for (b) model calibration. Initial conditions will be assigned to specify the distribution of water quality constituents for April 2008 at the beginning of the model calibration period. Lake station data will be used to assign an appropriate concentration for each grid cell and layer of the lake model. Observed time series data and vertical profile data obtained for each station will be used to compare lake model results for grid cells that are closest to the lake stations shown in Figure A-3. The lake monitoring data will be obtained from the OWRB 2008-2009 intensive surveys. The OWRB data set will be used since there are no other sources of ambient lake data for the calibration years of 2008-2009. There are no known limitations of the OWRB lake monitoring data sets.

Sediment Bed

Sediment bed data is needed for setup of the sediment transport and the sediment flux sub-models of the EFDC lake model. The initial distributions of bed solids content and bed porosity are assigned as input for the sediment transport model. The initial distributions of the organic content (C,N,P) and inorganic porewater nutrient (N,P) concentrations of the sediment bed are assigned as input for the sediment flux model. Except for measurements of sediment bed COD, TKN and TP for two sampling dates from the OWRB 2008-2009 survey, this type of sediment bed characterization data is not available for Lake Thunderbird. Estimates of appropriate values for these data types will be obtained instead from our previous Dynamic Solutions modeling studies of Tenkiller Ferry Lake (DSLLC, 2006) and Wister Lake (DSLLC, 2008). There is no limitation for the OWRB sediment bed data sets that will be used for model development. The primary limitations of the data sources for the other sediment bed data types is that the data that will be used to represent Lake Thunderbird will be obtained from studies for lakes other than Lake Thunderbird.

Atmospheric Forcing

Time series of atmospheric forcing data is needed for setup of the hydrodynamic model of the lake. In addition to the water temperature sub-model of the hydrodynamic model, solar radiation and cloud cover data is also used for the water quality model to simulate growth of algae. Wind forcing data is also used in the water quality model to simulate wind-driven reaeration of dissolved oxygen in the surface layer of the lake. The Oklahoma Mesonet program will provide all the atmospheric forcing data needed for model setup. An alternative data source for atmospheric forcing data is NOAA NCDC. The Oklahoma Mesonet data set, however, is readily available from DEQ and will also be used by DEQ for development of the HSPF watershed model. Since the watershed and lake model will be developed as a linked model framework for the lake, it is appropriate to use the same data source to represent atmospheric forcing for both the HSPF and EFDC models. There are no known limitations of the Mesonet data sets.

B10 DATA MANAGEMENT AND HARDWARE/SOFTWARE CONFIGURATION

Data Management Process

Consistent data management procedures will be used during pre-processing, model calibration and post-processing stages of the project. The various data sources described above in Section B9 will provide data for the project in a variety of electronic and hardcopy formats. All original data sources will be documented to identify contact information, formats, measurement units and filenames of data obtained. Data sets will be compiled as ASCII files, EXCEL spreadsheet files, database files and GIS map files. Input files for the EFDC hydrodynamic and water quality model will be organized and compiled in EFDC_Explorer. Location data originally reported as either geographic (latitude, longitude) or Oklahoma State Plane coordinates will be transformed to UTM Easting and Northing coordinates (as meters) with the horizontal projection based on NAD83 for Zone 14. Horizontal data will be converted to UTM Zone 14 NAD83 as the horizontal datum for the project using geographic software utilities (Global Mapper Version 9 and CorpsCon6 from the U.S. Army Corps of Engineers). Topographic and bathymetric elevation data will be transformed to NAVD88 in meters as the vertical datum if the original data is provided as a vertical datum based on NGVD29. The U.S. Army Corps of Engineers software utility (CorpsCon6) will be used to convert vertical datum of elevation data from NGVD29 to NAVD88. Consistent UTM coordinates are used for development of the EFDC computational grid scheme, georeferencing maps, locations of monitoring stations and other geographic landmarks for the project.

QA/QC checks will be performed to ensure that the units of observed data used for input to the model match the units required by EFDC. Salinity measurements in Lake Thunderbird, for example, are reported by OWRB as specific conductance. The input format for EFDC requires the conversion of specific conductance to salinity as parts per thousand (ppt). Station depth, topography and bottom elevation measurements will be checked to ensure that data sets are converted to meters and use NAVD88 as a consistent vertical datum for preparation of the input files for EFDC. QA/QC checks will be performed on all water quality files as a preliminary step in all data processing tasks for each individual file to flag missing data fields (blanks, zero, etc) and replace missing data with a consistent numerical value (e.g., -9) assigned for reformatting of all data files. QA/QC checks will also be performed to identify, flag and delete obviously erroneous data values (e.g., values out of normal range, non-numeric characters etc.). A documentation log will be maintained to track the origin of each data files from each data source provider. The data log will track data records that are identified as missing, out of normal range and/or erroneous values. Parameter names and units of measurement for original data source files will be documented for all data fields contained in each file.

Personnel

The Dynamic Solutions Project Leader will have primary responsibility for performing all tasks related to data management. He will coordinate closely with the DEQ Project Manager to obtain data files needed for the project and to ensure that the data provided in the source files is accurate and unambiguous. The Dynamic Solutions Project Leader will be assisted, on an as needed basis, by other staff from Dynamic Solutions.

Migration/Transfer/Conversion

Dynamic Solutions routinely prepares and exchanges data and reports electronically in a variety of formats including any format available in Microsoft Word 2007 (doc/docx), Microsoft Excel (XLS/XLSX, CSV, TXT, DBF, etc). Dynamic Solutions also generates Portable Document Format (pdf) files using Adobe Acrobat 8, and processes data from the EPA's STORET database, NOAA and USGS databases, and many other state and local agency database sources to acquire and use data necessary in a modeling project. During the course of the project, input files, model results files and deliverables will be uploaded to the Dynamic Solutions FTP site to make those files accessible to the DEQ Project Manager. Dynamic Solutions maintains a modern e-mail system and a dedicated FTP site to facilitate secure data exchange with clients and other authorized people needing access to the large electronic files typical of our watershed model and multi-dimensional hydrodynamic and water quality modeling projects. Usernames and passwords will be provided by Dynamic Solutions to the DEQ Project Manager as an authorized person to access project files. The Dynamic Solutions Project Leader will have primary responsibility for performing tasks related to the transfer of project files to the Dynamic Solutions FTP site. Current versions of the EFDC model and EFDC_Explorer files used for the project will be made available to the DEQ Project Manager from the Dynamic Solutions FTP site. At the conclusion of the project, the executable files for the EFDC model, EFDC_Explorer files, HSPF-EFDC pre-processing linkage software and post-processing codes, original raw data sets and reformatted files, EFDC model results and project deliverables will be written to external portable hard drives as (a) deliverable to the DEQ Project Manager and (b) for archiving at Dynamic Solutions headquarters office in Knoxville, Tennessee.

Hardware/Software Requirements

The data processing equipment that will be required for the development of the EFDC model of Lake Thunderbird are PC-based desktop and laptop computers configured with Microsoft Windows Vista and/or Windows XP Professional operating systems. The EFDC model, written in Fortran 90, is compiled using Compaq Visual Fortran-90. The EFDC model is executed from EFDC_Explorer in an MS-DOS window and requires a dual core 2.66 GHz Pentium processor, a 32-bit processor with 2 GB RAM and more than 10 GB available as hard disk space to achieve efficient runtimes. A typical one to two year run with an EFDC model will generate output files that can require about 5 GB or more of space available on the hard drive. For EFDC modeling projects that have been recently conducted by Dynamic Solutions, the elapsed runtimes for a one year hydrodynamic, sediment transport and water quality model simulation ranged from 6 to 16 hrs. These runtimes are based on time steps of 6 to 10 seconds, model domains of 700 to 2000 horizontal grid cells and 4 vertical layers.

The EFDC_Explorer pre- and post-processor software is written and compiled in Visual Basic. Time series results generated by the HSPF watershed model are written as ASCII text files for model-data comparison and post-processing linkage with the EFDC model. Input files for EFDC are all based on ASCII text files that can be created and edited within EFDC_Explorer. The

EFDC model writes binary output files for post-processing and display in EFDC_Explorer. All input and output files will be created and stored as ASCII text files, binary files and Excel spreadsheet files on (a) Dynamic Solutions network hard drives and (b) removable external hard drive media for backup and archiving of all project files. Backup copies to the hard drive of a network computer are created on a daily basis, as needed, at Dynamic Solutions to prevent potential data losses as changes are made to the EFDC model code, EFDC_Explorer code or custom computer programs written for project-specific pre- and post-processing tasks. Backup of project files is performed on a weekly basis with files written to removable hard drive electronic media. At the conclusion of the project, executable files for the EFDC model, the EFDC_Explorer interface, the HSPF-EFDC linkage software, other pre-post processing programs, raw data sets and reformatted input files, EFDC model results and project deliverables will be written to removable hard drive media for archiving at Dynamic Solutions in Knoxville, Tennessee. At the conclusion of the project, Dynamic Solutions will provide technical assistance to DEQ staff to ensure that the current versions of EFDC and EFDC_Explorer software and input/output files for the EFDC model calibration runs can be installed and operate properly on DEQ Windows-based computers.

Backup/Disaster Recovery

Backup files for a project are created at Dynamic Solutions on a weekly basis to prevent potential data losses. As changes are made to EFDC model code, EFDC_Explorer software, model input files, deliverables or custom computer programs written used for HSPF-EFDC pre-processing linkage and other pre- and post-processing tasks, files are backed up to a hard drive of a network computer, as needed, on a daily basis. Project files archived on hard drives of separate network computer(s) are backed up to removable media (Digital Versatile Disc's or removable hard drives) on a weekly basis. The Dynamic Solutions Project Leader will have primary responsibility for backup of the EFDC model project files. The Dynamic Solutions Project Leader will have primary responsibility for ensuring that the current versions of the EFDC model code and the EFDC_Explorer software files are backed up to both hard drives of network computers and removable electronic media . In the event of a catastrophic failure of files created and stored on the hard drive of the primary computers used by Dynamic Solutions for the Lake Thunderbird project, backup files will be accessed and restored from either network computer hard drives and/or removable hard drives. Backup files for the project will be maintained at our Knoxville TN headquarters office of Dynamic Solutions and our off-site office location in Northern Virginia near Washington DC.

Information Dissemination

Project updates will be provided to the DEQ Project Manager in periodic telephone discussions, e-mail communications and monthly progress reports. Input data and model outputs resulting from the project described in this QAPP will be accessible to interested Stakeholders and the general public by written request to the DEQ Project Manager. Key findings that result from the watershed and lake models used to support the determination of load allocations for the Little River watershed may be summarized in "fact sheets" prepared and distributed by either DEQ and/or EPA Region 6.

Project Data Management

Original data source files will be reformatted as standardized sets of ASCII file formats for compilation of the project database for pre-processing, post-processing (model output) and model-data comparisons for evaluations of model performance. Data management procedures adopted for this modeling project will be implemented to facilitate tracking of original data sources, data conversion and any other manipulations needed for compilation of the data sets for input to EFDC and calibration of the hydrodynamic and water quality models. Compilation of the project database will require processing of numerous individual files obtained from a variety of data sources (e.g., OWRB, DEQ, USEPA, USGS, NOAA NCDC etc.) to develop spatial and time series data sets. A standardized ASCII file format containing spatial (as UTM Zone 14, NAD83, meters), bottom elevation and depth (as NAVD88, meters) and time (date/time). Date and time (as local Central Standard Time, CST) are converted to decimal Julian days relative to January 1, 1990 for model setup and model calibration. This space, depth and time coordinate convention has been adopted for all Dynamic Solutions surface water modeling projects to facilitate a consistent pre-processing procedure for compilation of data obtained from original sources files. Original data sources, data filenames and units of measurement for data sets are recorded in project notebooks and any software code written to process original data sources. Any manipulations, transformations, conversions, assumptions, or filling in missing data codes needed to write the original data into the standard database format are recorded for each data source in project notebooks as well as e-mails or any program code written for pre-processing purposes.

SECTION C: ASSESSMENT AND OVERSIGHT

C1 ASSESSMENT AND RESPONSE ACTIONS

Types of assessments and response actions for activities applicable to the modeling work that will be performed under this QAPP include the following:

- Data quality reviews for XY coordinates for shoreline, topography and lake bottom elevation, and locations for meteorology and precipitation stations, flow gages, and water quality monitoring stations;
- Data quality reviews for outliers identified from time series plots for precipitation, streamflow and water quality constituents;
- Model setup reviews for computational grid, initial and boundary conditions, and external forcing functions;
- Model calibration reviews for acceptable ranges of model parameters/coefficients and comparison to model performance criteria; model coefficients will be adjusted as needed to attain credible model calibration;
- Monthly progress reports which will briefly summarize work accomplished during a reporting period, any problems encountered and resolution of such problems, and work anticipated to be completed during the following reporting period;
- Technical memoranda and project reports which will document data sources, modeling approach, model results, and evaluation of findings; draft documents will be submitted to DEQ Project Manager and EPA Region 6 for review and comment; final report documents will incorporate comments where appropriate.

Data sets acquired for the purposes of model setup will be evaluated by the Dynamic Solutions Project Leader and Project Engineers as the data sets are acquired and processed for model development. Data types, listed in Table B-1, that will be used for model setup will be assessed once during the project. After the different data sets are evaluated and accepted for use in building the model, no further assessments of those data sets will be performed for the project. Details of this part of the project are presented in Section D2 of this QAPP. Data generated as model results during model calibration will be compared to observed data sets and evaluated for model performance by the Dynamic Solutions Project Leader and Project Engineers as various model coefficients are selected and tested during the model calibration process. Once the model is considered to be calibrated, model results will also be evaluated by the DEQ Project Manager to verify, for example, that Dynamic Solutions, as the contractor, is compliant with the QAPP requirements for model development. Other oversight activities performed by the DEQ Project Manager after the model is considered to be calibrated may include a review of model performance assessments and whether or not the target criteria for hydrodynamic and water quality state variables have been attained for model calibration.

All modeling data and project deliverables will be internally quality controlled by the Dynamic Solutions Project Manager internal review process. The DEQ Project Manager will maintain overall responsibility for examining the results of the contracted work to ensure that methodologies and processes are consistent with the procedures outlined in this modeling QAPP. The development of the hydrodynamic and water quality model is under the design, control, and direction of the Dynamic Solutions Project Leader. The Project Leader is best equipped to handle computer input data selection, model calibration, model outputs and reporting of results and findings.

The different types of assessments that will be performed during the performance of this project include the following:

Surveillance Activities

To ensure that the technical aspects of the effort are being properly implemented, the status and progress of all work performed by the Dynamic Solutions Project Leader and other staff members for the development of the hydrodynamic and water quality model will be monitored on a weekly basis by the Dynamic Solutions Project Manager. The Dynamic Solutions Project Manager, in turn, will keep the DEQ Project Manager informed of the status of work during the course of the project. If, based on monitoring of the activities of the project, problems arise that could impact the ability of the project team to achieve the goals of the project, then appropriate corrective actions will be identified and implemented jointly by the Dynamic Solutions Project Manager and the DEQ Project Manager.

Model Calibration

During the model calibration phase of the project, assessments will be made continuously as to the appropriateness of the range of values assigned to adjustable kinetic coefficients and model parameters. The assessor for this project will be the Dynamic Solutions Project Leader. Project oversight will be provided to Dynamic Solutions by the DEQ Project Manager. Others are available for technical assistance as requested, including project staff from Dynamic Solutions, technical staff from DEQ and the technical staff in the EPA Region 6 TMDL Program. The DEQ Project Manager has the ultimate authority to continue, or modify work, in a significant fashion, including issuance of a stop work order for the project. The Dynamic Solutions Project Leader will maintain a hard copy journal record (i.e., modeling log) of this project, such that input and output of computer analyses at various steps in the development of the model can be tracked and reproduced if necessary.

Corrective Action

The Dynamic Solutions Project Manager is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and any corrective actions are maintained by the DEQ Project Manager and Dynamic Solutions. Corrective action documentation will be submitted, if necessary, to the DEQ Project Manager with progress reports. If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements, or contracts, between participating organizations. The Dynamic Solutions Project Manager and/or the Dynamic Solutions QA Officer are responsible for documenting deficiencies and non-conformances to their management. These individuals will also submit Corrective Action Reports to the DEQ Project Manager with the next progress report due after the deficiency and/or non-conformance has occurred.

A "Corrective Action Form" will be used by the Dynamic Solutions Project Leader to track and solve problems and/or issues related to the project. Corrective Action Reports are intended to identify any deficiencies and non-conformances occurring in a project. The cause(s) and program impacts are discussed. The completed corrective actions are documented. A report is submitted to the DEQ Project Manager with the first Corrective Action Report included in the progress report occurring after the deficiencies and/or non-conformance was identified. A sample Corrective Action Form is presented in Appendix A of this QAPP.

C2 REPORTS TO MANAGEMENT

Reports to Dynamic Solutions Project Management

The Dynamic Solutions Project Manager is provided with weekly status reports on all ongoing projects by Dynamic Solutions Project Leaders. Project status reports include an overview of work accomplished to date; identification of data that has been obtained and identification of data that has not yet been obtained; and identification of problems and/or issues and any corrective actions related to successful completion of task(s) related to the project. A summary of resources expended and resources remaining in the task and/or project budget will also be provided as part of a project status report. Weekly status reports are typically verbal with occasional additional documentation by e-mail.

Reports to DEQ Project Management

Periodic memoranda and telephone communications from the Dynamic Solutions Project Leader to the DEQ Project Manager provides the most effective formal means of communicating progress of this modeling project. At a minimum, a status report, written as a brief technical memorandum, will be provided in this fashion at the completion of each task of the project. Formal deliverables of the Lake Thunderbird hydrodynamic and water quality model project will include the following items:

1. This Modeling QAPP document,
2. Monthly Progress Reports,
3. EFDC model input/output files,
4. Current Dynamic Solutions version of EFDC executable files,
5. Current Dynamic Solutions version of EFDC_Explorer software, and
6. Draft and final reports.

Monthly Progress Report will be prepared by Dynamic Solutions to briefly detail activities for each task. Reports should provide enough information so that the DEQ Project Manager can evaluate the status and progress of the modeling effort. The Dynamic Solutions Project Leader is the logical individual to have responsibility for providing the necessary reports to management.

Dynamic Solutions will prepare and submit written progress reports to the DEQ Project Manager. The monthly written progress reports will always match the period of time billed in our monthly invoices for this project. For this project, we will include all of the information specified in the Scope of Work in our written progress reports, including

- Contract number, reporting period, and Dynamic Solutions Project Manager contact information,
- Report period progress and activities completed toward completion of deliverables, including those regarding QA,
- List of deliverables (draft and final) submitted, including dates submitted to DEQ and EPA Region 6; list of upcoming deliverables,
- Planned projected activity for the next reporting period,
- Problems, issues, or deviations from the approved QAPP, schedule, and budget; suggested resolutions for problems, and
- Financial status, including hours and costs for the reporting period, accumulated costs, and available funds remaining.

SECTION D: DATA VALIDATION AND USABILITY

The purpose of Section D of this QAPP document is to describe the approach that will be used to assess the usability of the hydrodynamic and water quality model results generated for the Lake Thunderbird study. The elements of Section D will be enacted at the conclusion of the hydrodynamic and water quality modeling study to confirm that the steps of the modeling study were followed correctly to produce model outputs that will meet the objectives of the project. The end data user for the results of the hydrodynamic and water quality modeling study of Lake Thunderbird is the DEQ Project Manager. The DEQ Project Manager will use data generated by the hydrodynamic and water quality model to prepare a watershed management and load allocation report which may recommend (a) loading limits on nutrients and solids from land use dependent watershed runoff to Lake Thunderbird and/or (b) in-lake remediation actions to improve water quality conditions to meet water quality targets for the lake. The DEQ Project Manager may recommend specific load allocations for Lake Thunderbird and/or in-lake mitigation practices expected to improve water quality conditions. The scope and scale of the development of a hydrodynamic and water quality model of Lake Thunderbird is such that the primary person responsible for data selection, data use, and reconciliation, is the DEQ Project Manager. The DEQ Project Manager may choose to solicit input from others, including the Dynamic Solutions Project Leader, the DEQ Planning Section Manager for the Water Quality Division, the DEQ QA Coordinator, the USEPA Region 6 and/or DEQ QA Officer, or others.

Data validation and usability activities for the Lake Thunderbird modeling project include the following three QAPP elements:

- D1 Departures from Validation Criteria,
- D2 Validation Methods, and
- D3 Reconciliation with User Requirements.

D1 DEPARTURES FROM VALIDATION CRITERIA

The Dynamic Solutions QAO will be responsible for ensuring that all model input and output data are properly reviewed and verified, and submitted in the required format to the DEQ Project Manager. The Dynamic Solutions Project Leader is responsible for calibration of the model and comparison between the model output and observed data. Finally, the Dynamic Solutions Project Manager, with the concurrence of the Dynamic Solutions QAO, are responsible for verifying that all data and model outputs to be reported meet the objectives of the project and are suitable for reporting to DEQ.

In Section A7, a discussion is presented outlining the weight of evidence approach that will be used by Dynamic Solutions to evaluate the performance, and ability, of the hydrodynamic and water quality model to accurately represent lake circulation and biogeochemical interactions that control the distributions of nutrients, algae, sediment and dissolved oxygen in Lake Thunderbird. The hydrodynamic and water quality model will be calibrated using data collected by OWRB from April 2008 through April 2009. At each step of the model calibration process, as detailed in Section A6 of this QAPP document, the Dynamic Solutions Project Leader will review the graphical comparison of model-data results using the weight of evidence approach for evaluating model performance as discussed in Section A7. The DEQ Project Manager, as the end user of the hydrodynamic and water quality model results, will also evaluate the performance of the model results using the weight of evidence approach described in Section A7.

D2 VALIDATION METHODS

During the initial stages of the project, a variety of different data sets will be identified, acquired and compiled for preparation of the input files needed for the development, calibration and validation of the EFDC hydrodynamic and water quality model. Data requirements for the EFDC hydrodynamic and water quality model are presented in Section A7 of this QAPP document. As the data sets are reviewed and organized for input to the model, checks will be made to flag missing and erroneous data and to ensure that the correct units are being used to prepare the input data for EFDC. Appropriate data conversions will be made as needed and documented. The various data sets will also be assessed to check the magnitudes and numerical ranges of the data to identify, and eliminate, any apparent outliers in the acquired data sets with appropriate consultation with project participants. As discussed in Section B9 Non-Direct Measurements, evaluations based on comparisons of historical data sets will include checks on the observed maximum and minimum ranges of water quality constituents and whether or not there are any outliers in the data sets that should be discarded. One way that outliers can be identified is by visual inspection of data plots combined with best professional judgment based on knowledge of what is considered a reasonable range of values for a specific water quality constituent. It is unlikely, for example, that water temperature will exceed 40 C in Lake Thunderbird. Because many data sets used in building surface water models typically conform to a Gaussian (i.e., normal) distribution, outliers are defined as values determined to be less than (or greater than) the numerical range defined by three standard deviations from the mean value. No outlier data will be excluded from the input and calibration data sets without due process. The DEQ Project Manager will make final decisions related to the disposition of any outlier data identified during model setup and model calibration. As the final step in the assessment of data acquired for the project, georeferenced data (e.g., locations of monitoring stations), will be checked to ensure that the geographical position of the data is correctly located within the spatial domain of the model. Corrections will be made, if needed, to assign the georeferenced data to the correct latitude and longitude.

Before the watershed runoff and lake model framework can be applied for load allocations or evaluations of in-lake mitigation strategies, the model framework will be developed using a two-stage process for (1) model setup using observed data to describe tributary inflows from the watershed and (2) model calibration using HSPF watershed model results to describe tributary and nonpoint source inflows to the lake. A set of adjustable model coefficients and model parameters will initially be assigned to construct a simulation based on inflows characterized by observed tributary flows and water quality data collected during April 2008 through April 2009. The objective of the initial model setup effort is to obtain a reasonable agreement between the model results and the observed in-lake water quality data. After model setup is satisfactorily completed using the observed tributary inflow data, the HSPF watershed model results for tributary and nonpoint source loading that will be provided by

DEQ to Dynamic Solutions will then be used to update the watershed loading for input to the EFDC lake model. Various model coefficients may then be adjusted using a systematic iterative process to obtain good agreement with the model results using the new HSPF results time series data that will be generated by the DEQ. The objective of this two-stage process is to obtain a successful calibration of the Lake Thunderbird model to provide a technically defensible tool that can be used by DEQ for load allocations and evaluations of the effectiveness of in-lake mitigation options. The performance of the calibrated model framework will be evaluated using the "weight of evidence" approach presented in Section A7.

In order to confirm the acceptability of the model parameters assigned as time varying input data for watershed loading and water quality state variables resulting from variability of precipitation and pollutant loads and water supply withdrawals and outflow from the lake, the results of the lake model will be compared to data collected at stations in the lake. Model-data comparisons will be prepared as (a) time series plots and (b) vertical profiles for EFDC grid cells that match the station locations. At each step in the development of the model, the "weight of evidence" approach described in Section A7 will be used in an ongoing and iterative process during model development to evaluate how well the lake model is able to reproduce the observed spatial, vertical and temporal distributions of water quality constituents including dissolved oxygen, algae, nutrients and turbidity-related state variables. As described in Section A6, each step in the development of the model will be internally reviewed, and approved, by the Dynamic Solutions Project Leader before the Dynamic Solutions modeling team continues with the next step in the development of the model.

Verification and integrity review of output data and associated calculations will be performed using self-assessments and peer review, as appropriate to the project task, followed by technical review by the Dynamic Solutions Project Leader. The model results and associated calculations will be evaluated against project objectives (Section A7) and will be checked for errors, especially errors in transcription, calculations, units conversion and data input. Potential outliers in input data are identified by visual examination for unreasonable data, or identified using computer-based statistical techniques. If an error or potential outlier is identified, or any other issue arises, the Dynamic Solutions staff member responsible for generating the data is contacted to resolve the issue. Issues which can be corrected will be corrected and documented electronically or by initialing and dating the associated hard copy paperwork. If an issue cannot be corrected, the Dynamic Solutions staff member will consult with the Dynamic Solutions Project Leader and, if necessary, the Dynamic Solutions Project Manager to establish the appropriate course of action, or the data associated with the issue will be rejected. The Dynamic Solutions Project Manager, with the concurrence of the Dynamic Solutions QA Officer verifies that the data meet the data quality objectives of the project and are suitable for reporting to the DEQ Project Manager.

D3 RECONCILIATION WITH USER REQUIREMENTS

A watershed management plan will be developed by DEQ for Lake Thunderbird to recommend the appropriate reductions in nonpoint source loading of constituents associated with dissolved oxygen, nutrients, organic carbon, sediments and algae to mitigate the effects of excessive pollutant loading on the known impairments of the lake. The lake model results will provide the technical basis for a watershed-based load allocation determination and, perhaps other in-lake remediation actions, expected to restore and maintain water quality in Lake Thunderbird. The model framework, based on the DEQ-developed HSPF watershed runoff model and the Dynamic Solutions-developed EFDC hydrodynamic and water quality model, is designed to quantitatively describe the cause-effect interactions between (a) external forcing of precipitation, runoff and pollutant loading from the watershed (non-point sources); (b) lake circulation; and (c) the kinetic processes and interactions of the water quality constituents of concern within the lake.

The results of the Lake Thunderbird modeling study will be reviewed by the Dynamic Solutions Project Leader to assess the usability of the model results, in light of any QA/QC issues identified, to provide the hydrodynamic and water quality model results for determination of the load allocations that will be developed in close coordination with the DEQ Project Manager. Output data and model results generated with the model framework will be presented in the project deliverables as graphical comparisons of observed and model-generated water quality constituents. Model-data comparisons will be prepared as (a) time series plots and (b) vertical profiles to show how the model results compare to observations collected for selected station locations within the EFDC lake model domain. The qualitative visual evaluation of model credibility will be complemented by a quantitative numerical evaluation of model performance criteria and statistics where the credibility of the lake model will be assessed based on a comparison of model results and observed data. Section A7 describes the model performance criteria and statistics that will be used to assess the capability of the model to represent observed conditions in the lake.

Using the “weight of evidence” approach discussed in A7 Data Quality Objectives (DQO) and Criteria, a determination will be made of the overall technical credibility of the model framework. If the visual comparison of model results with observations appears to be in reasonable agreement and the model performance statistics show that the model can meet the specified target criteria for the key state variables, then the model framework will be considered to be technically defensible, and therefore useable, to provide hydrodynamic and water quality model results for load allocations and evaluations of in-lake mitigation strategies by the DEQ Project Manager.

If performance measures of the model do not meet the project’s requirements for DQOs, the data sets used to construct the model and the assignment of model coefficients will be re-evaluated to identify possible reasons for failure to meet the model performance criteria. Decisions will be made by the Dynamic Solutions Project Leader about the (a) validity of the input data and observed data used to construct the model and the (b) steps needed to complete development of the model to achieve satisfactory performance. If, after checking the data used to build the models, satisfactory performance is still not achieved then a discussion of the possible explanations for the poor performance of the model will be presented and discussed in the deliverable report prepared for this study. Assuming that the model may still be able to be applied for a load allocation even though the model may not achieve the desired level of performance, then a higher margin of safety would be used to estimate more conservative load allocations to compensate for the performance of the model.

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Appendix A

Corrective Action Form
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DATE:		**CAF Number**

What is the problem? Describe below.

Would you describe this as a Major or Minor problem?

Major ➢ ☐ **Minor** ➢ ☐

What are the causes of the problem?

Corrective Action Form

DATE:		**CAF Number**
How do you propose to eliminate the problem?		
What is the justification for your proposed fix?		

Submitted by: **Approved by:**

Date: **Date:**

Follow-up: Was the problem solved? Describe.

Program Manager Approval: ____________________________ **Date:**_________________

Q/A Officer Review: ___________________________________ **Date:**________________

Attachment #1 – OWRB QAPP for Lake Thunderbird Monitoring Survey of 2008-2009

Attachment #2- DEQ QAPP for Lake Thunderbird HSPF Watershed Model